2 Prototype Clark's Ferry Section

Prototype Data Collection

The ISWS collected physical data on the hydrodynamic changes associated with tow and barge traffic movement on the Upper Mississippi River System. These data were collected from both the Illinois and Mississippi Rivers. The detailed report on the Clark's Ferry prototype experiments is given in Bhowmik, Soong, and Xia (1994).

The Clark's Ferry site is located at River Mile 468.2 in a relatively straight reach as shown in Figure 1. The prototype measurement site is in Pool 16, approximately 18 km (11 miles) upstream of the dam. Like many areas of the Upper Mississippi River, Clark's Ferry has submerged dikes located about 300 m apart. The dikes in the Clark's Ferry reach are angled upstream and located on the left descending bank. A reconnaissance trip, before the actual field data collection, gathered information on site characteristics, bathymetry, cross-sectional profiles, discharge, suspended sediment, and bed materials. The actual field data collection trip included collecting data on ambient conditions and during an event. Data were taken for three periods: (a) pre-passage, (b) actual passage, and (c) post-passage. Trip 1 field data were collected for seven consecutive days (May 16-22, 1991), and trip 2 for four consecutive days (October 17-20, 1991). Trip 1 was conducted during an intermediate flow period and trip 2 was conducted during a low flow. Figures 2 and 3 show cross sections for trips 1 and 2, respectively.

Prototype Instrumentation

Instrumentation used for data collection were: (a) five interocean current meters (model S4's), (b) two Marsh McBirney (MMB) 527 velocity meters, (c) six MMB511's, and (d) one wave gauge. The instruments were placed in the experimental reach for data collection. Velocity data in both the x- and y- directions were sampled at one sample per second. Positive x velocities were downstream and positive y velocities were toward the left bank. Wave data were sampled at 10 samples per second.

For trip 1, velocity meters were deployed as shown on Figure 4. Two MMB511's at 28.0 m from the right bank were mounted at vertical heights of 0.33 and 1.52 m above the river bottom. Three MMB511's at 43.0 m from the right bank were mounted at vertical heights of 0.36, 1.62, and 2.53 m above the riverbed. These meters were utilized to measure the variations of horizontal velocity components at various heights above the bed. The trip 1 wave gauge was 22.87 m from the right bank.

For trip 2, the velocity was measured at the locations shown in Figure 5. Three MMB511's at 41.1 m from the right bank were mounted at vertical heights of 0.51, 1.24, and 2.16 m above the riverbed. Two MMB511's at 68.6 m from the right bank were mounted at heights of 0.50 and 1.21 m above the bed. The trip 2 wave gauge was 18.3 m from the right bank.

Events

Discharges and stages were measured at different times during trip 1 and trip 2. Table 1 shows discharges, velocities, flow depths, and water surface elevations. The average water surface slope on this reach was 0.333 ft/mile (0.679 m/km) during trip 1 and 0.060 ft/mile (0.122 m/km) during trip 2. These slopes are determined by the daily stages at river mile 473.75 and river mile 468.2.

Trip 1 monitored 33 barge events and trip 2 monitored 28 barge events. Tables 2 and 3 (trips 1 and 2, respectively) give the name, date, draft, barge configuration, tow speed relative to earth, distance of the center line of the tow to the bank, and the tow direction for each event.

Data Filtering

Prototype and physical model data contain velocity and water level changes not caused by the tow. These changes included: the normal fluctuations found in turbulent flow, eddies shedding from upstream bends, and changes from upstream structures or tributaries. Model to prototype comparisons must be based on tow-induced motion and not on extraneous components found in both the prototype and physical model. Filtering out unwanted information, if a limiting frequency can be identified, is one alternative. Since prototype tows are generally 300 m long and travel at about 3 m/sec, the time the tow is adjacent to the measuring point is about 100 sec, which roughly defines the period of the event and leads to a frequency of interest of 0.01 Hz. Data were filtered at a limiting frequency of 0.02 Hz to make certain that tow information is not filtered. Fluctuations above a certain frequency needed to be filtered out because model velocity, prototype velocity, and wave meters had different frequency response. For example, the prototype electromagnetic velocity meters sampled at 1 Hz, whereas the acoustic Doppler velocity meters used in the physical model sampled at 25 Hz, equivalent to 5 Hz in the prototype. A fast Fourier transform (FFT) filtered out components of velocity or drawdown occurring at frequencies greater than 0.02 Hz in both the

prototype and the physical model. Physical model data were filtered after scaling values to their prototype equivalent.

Tows Selected for Comparison to Physical Model

To achieve the first objective of the study, validation of the model, prototype events were selected to simulate in the physical model based on the following:

a. Number of meters functioning during experiments. Some events were not used because one or more meters malfunctioned.

b. Tow configuration and draft. To simulate tow events producing the maximum deviation from ambient conditions, only loaded barges that were three wide by four or five long were used in the adjustment/ calibration of the physical model. Events producing the maximum deviation from ambient were desired because small deviations from ambient conditions are difficult to extract from the ambient fluctuations found in the river. Also note that the 3-wide by 5-long, loaded tow is a standard configuration.

The eight tows initially selected were *JD Wofford, Pearl B.*, and *Donnie Ray Jr.(2)* from trip 1 and *Conti-Nan(1), Kevin Michael, Deborah Valentine, Kathy Ellen*, and *Cooperative Ambassador* from trip 2.

Definitions

Terms used herein are defined as follows:

a. Left bank, or right of the thalweg, refers to a position in the cross section when looking at the cross section in a downstream direction.

b. Ambient velocity is the velocity measured without tow traffic effects but close enough to the tow passage to eliminate variations due to flow and/or stage changes. At Clark's Ferry the prototype data presented for the *Kevin Michael* suggest that ambient velocity should be measured over at least 5 min to obtain a representation of the mean.

c. Impact velocity is the maximum velocity or minimum velocity that occurs during the tow event for a given mechanism. For example, the impact velocity from return currents would be the maximum velocity (for upbound tows) or minimum velocity (for downbound tows) that occurs adjacent to the vessel. The return velocity is the difference between the impact velocity and the ambient velocity.

Ambient Velocity Fluctuations

The variation of the ambient velocity about the mean could establish the significance of tow-induced changes. For example, if natural stream velocity variations over periods of about 100 sec (100 sec based on duration of tow event) are ±5 cm/sec, one might conclude that tow-induced changes less than 5 cm/sec are no different than the natural variations. The filtered prototype data were analyzed for the maximum and minimum values over a 100-sec time interval prior to any tow effects. The relative ambient velocity variation shown in Table 4 was found by dividing the difference between maximum and minimum values by two and then dividing by the mean ambient velocity. Using an average value from Table 4 as a guide, natural velocity fluctuations (with periods similar to a tow event period) fluctuate about the mean ambient current an average of ±20 percent and ±15 percent for the trip 1 and trip 2 data, respectively. The unfiltered prototype data for the eight verification tows were analyzed for standard deviation as a percentage of the mean ambient velocity at the velocity probe (referred to as the coefficient of variation, *CV*). *CV* values for trip 1 and trip 2 were 0.13 and 0.17, respectively. Whether using the maximum fluctuation over the duration of a tow event or the standard deviation, fluctuations in the river probably mask any tow-induced return velocities that are less than about 15 percent of the mean ambient velocity.

Variation in Prototype Data

It is important to recognize that the prototype data in the verification process are subject to variation caused by measurement inaccuracy in tow speed, tow draft, tow position, tow alignment, water velocity, water level variation, and ambient discharge. Also of concern is the following: lack of knowledge about the propeller speed, applied horsepower, shape of the barge bow and the variation in the prototype cross sections up- and downstream of the cross section measured by the ISWS. All barges selected for the prototype verification had a 2.74-m draft. The writers' experience suggests that the loaded barges' draft could have been ±0.15 m (6 in.). Tow alignment relative to the river axis could have been skewed by several degrees, resulting in an effective tow width greater than the sum of the barges' widths.

One of the greatest sources of uncertainty in the prototype data is extracting the tow impact from the ambient fluctuations in the river. This was not a problem for the trip 2 data, which were collected at low flow conditions. The relatively low return velocity (because of the large cross-sectional area) at Clark's Ferry in conjunction with the higher ambient velocities presents a problem for the trip 1 data. The changes induced by the tow in trip 1 are small and close to the magnitude of the natural velocity fluctuations having periods similar to the tow event. For example, the *JD Wofford* prototype data showed no significant change when the tow passed. The ambient velocity fluctuations from the filtered prototype data varied about an average of ±18.5 percent of the mean velocity, which in absolute

terms was about ±0.08 m/sec. The physical model data from *JD Wofford* showed that the average return velocity from the tow event was about 0.12 m/sec. The physical model value was difficult to determine because the physical model has variation about the mean of ±0.06 m/sec. Since the tow change and the natural variations are close in magnitude for the trip 1 experiments, only the five tows from the trip 2 data will be used to calibrate the physical model.

To screen the prototype data for possible inconsistencies, the Schijf (1949) equation was used to compute the average return velocity and drawdown (Table 5). The Schijf equation provides a cross-sectional average return velocity whereas the prototype data are near bottom velocity data from which a maximum value was extracted. While these two velocities are different, their ratio should be relatively constant at a given meter, and meters physically close to each other should not vary significantly. Each tow event's prototype data were examined for a similar ratio of maximum observed return velocity/Schijf average return velocity. The filtered data from each prototype velocity meter were analyzed for the maximum return velocity/ Schijf average return velocity (Table 6). Velocity meters not close to the channel boundary would be expected to give similar values for a given tow event. Meters 999, 1000, 1131, 834, 151, 832, 642, 040, and 332 from trip 2 are not close to the boundary. One would also expect meters 999 and 1000 to give similar results because they are at the same lateral position and are located away from the channel perimeter. Meters 1131, 332, and 642 should also give the same response because of their similar positions. Based on Table 6, the only velocity meters in question are 151, 832, and 834 for the *Deborah Valentine* event because their values are less than the value from the Schijf equation whereas other events are greater. Meters 332 and 642 will not be used in the calibration/ verification because they are the same distance from the boundary and give the same result as meter 1131. Meter 1000 was omitted because it was at the same lateral position as 999 and because the physical model velocity meter at the position of 1000 malfunctioned for many of the experiments.